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FOR

LINK QUALITY AGENT

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LINK QUALITY AGENT

CROSS-REFERENCE TO RELATED APPLICATION

5   The present application is a continuation of co-pending application Serial no. 09/782,956, filed February 13, 2001, the benefit of the priority date of which is claimed under 35 U.S.C. § 120.

BACKGROUND OF THE INVENTION

10   1.   Field of the Invention

The present invention is related to free space optical communication systems and, in particular, to an intelligent agent in a free space optical communication system.

2.   Background Information

15   Optical wireless transmission is way of providing multi-gigabit connectivity between two locations without the use of an optical fiber interconnection. At the transmitting end, an optical wireless system typically consists of an optical laser source, which is being modulated by a data source to produce and optically encoded data signal. The data source typically provides the intelligence or information to be transmitted, such

20   as data, audio, video, messages, etc. An optical amplifier may amplify the optical signal, which is then transmitted into the atmosphere (or free-space) through a transmitting telescope as an optical transmission beam towards a receiving telescope. On the receiving end of an optical wireless system, a receiving telescope collects part of the optical beam and focuses it as a light spot into a receiving optical fiber. The receiving optical fiber is

25   connected to a receiver/regenerator, which converts the optically encoded data signal back into an electrical data signal.

In an optical wireless system, the atmosphere is the propagation medium for the optical transmission beam (sometimes called a light beam). One drawback to using the atmosphere as the transmission medium is the effect that weather conditions have on the optically encoded data signal. For example, fog often causes the optical link to operate marginally, which means that the receiver may receive sufficient small packet handshaking signals, such as open shortest path first (OSPF) "hello" packets, but not enough of the transmitted data in large packets.

Normally, when data is not being received, the system would shift to a backup means to deliver data. In the situation in which the system is marginal, however, the system may not shift to a backup means to deliver the data and much of the data is lost. Alternatively, the system may shift to a backup means when the receiver does not receives sufficient "hello" packets and return to the primary means to deliver data when the receiver does receive sufficient "hello" packets. The term "flapping" describes the condition in which the optical link goes in and out of tolerance numerous times such that the router has to excessively reconfigure the means to deliver data. Flapping consumes a large percentage of bandwidth and therefore must be controlled. Moreover, in this situation, the system experiences high link error rates, which results in the system having to retransmit packets. Retransmission of packets seriously degrades link bandwidth for data.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is best understood by reference to the figures wherein references with like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. The drawing in which an element first appears is indicated by the leftmost digit(s) in the reference number in which:

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Figure 1 is a high-level block diagram of a communication system according to an embodiment of the present invention;

Figure 2 is a more detailed block diagram of the communication system in Figure 5   1; and

Figure 3 is a flowchart illustrating an approach to link quality monitoring.

DETAILED DESCRIPTION

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Figure 1 is a high-level block diagram of a communication system 100. In the following description, numerous specific details, such as particular processes, materials, devices, and so forth, are presented to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that 15   the invention can be practiced without one or more of the specific details, or with other methods, components, etc. In other instances, well-known structures or operations are not shown or described in detail to avoid obscuring aspects of various embodiments of the invention.

20   Some parts of the description will be presented using terms such as agent, link, light beam, transceiver, photon, remote monitors, and so forth. These terms are commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art.

25   Other parts of the description will be presented in terms of operations performed by a computer system, using terms such as receiving, detecting, collecting, transmitting, and so forth. As is well understood by those skilled in the art, these quantities and operations take the form of electrical, magnetic, or optical signals capable of being

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stored, transferred, combined, and otherwise manipulated through mechanical and electrical components of a computer system; and the term "computer system" includes general purpose as well as special purpose data processing machines, systems, and the like, that are standalone, adjunct or embedded.

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Various operations will be described as multiple discrete steps performed in turn in a manner that is most helpful in understanding the invention. However, the order in which they are described should not be construed to imply that these operations are necessarily order dependent or that the operations be performed in the order in which the

10 steps are presented.

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, process, step, or characteristic described in connection with the embodiment is included in at least one embodiment of the present

15 invention. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

20 The communication system 100 can be any communication system that employs an analog transmission medium or that operates in an analog encoding environment. The communication system 100 may be an optical system that uses the atmosphere as the transmission medium and in which data is transmitted and received via an optical carrier. In other embodiments, the communication system 100 is an any wireless communication

25 system where the atmosphere is the transmission medium and data is transmitted and received across an analog link via a radio frequency (RF) carrier, a microwave carrier, and the like.

The system 100 as illustrated in Figure 1 includes a transceiver 102 and a transceiver 104, which to transmit and receive traffic in free space via an antenna 106 and an antenna 108, respectively. Traffic can be customer traffic or test traffic, which are small bursts of data.

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In one embodiment, the transceiver 102 may be a single access transceiver (SAT) and the transceiver 104 may be a holographic photon collector (HPC). Either the transceiver 102 or 104 may be a reflective photon collector (RPC), a multiple access transceiver (MAT), an SAT, an HPC, or any other device to transmit and receive a light

10   beam from free space.

Transceivers typically have analog signal strength detectors. One such analog signal strength detector is an avalanche photodiode (APD), which is a photon detector. Transceivers also may employ techniques to attenuate the light beam, such as filter

15   wheels. In operation, if the photon count for the light beam at the detector is low, the light beam attenuator can be adjusted to allow more photons to be received.

The antennas 106 and 108 can be telescopes. Transceivers and antennas suitable for implementing the transceiver 102 ad 104 and the antennas 106 and 108 are well

20   known.

The transceiver 102 is coupled to a network device, such as a distribution switch 110, which filters and forwards packets. In one embodiment, the distribution switch 110 allows multiple Ethernet connections. Network devices are well known and distribution

25   switches suitable for implementing the distribution switch 110 are well known. The distribution switch 110 is coupled to a network router 112 and to one or more transceivers 113.

The transceivers 113 are typically similar to the transceiver 102 and the transceiver 104, which are well known.

The network router 112 moves packets of data from source to destination, typically by passing messages and analyzing a routing table to determine the best path for packets to take. The network router 112 also configures the best route for the packets to reach their ultimate destination. Network routers suitable for implementing the network router 112 are well known. The network router 112 is coupled to a network backbone 114.

The network backbone 114 generally is a connection of multipoint hubs (MPH), customer premised equipment (CPE), and/or points of presence (POP). The multipoint hubs may be connected to each other via reflective photon collectors (RPC). In an embodiment, the network of multipoint hubs and reflective photon collectors is the network backbone 114. Backbones suitable for implementing the network backbone 114 are well known.

The transceiver 104 is coupled to a network device, such as a distribution switch 120, which may be similar or identical to the distribution switch 110. The distribution switch 120 is coupled to a network router 122.

The network router 122 in an embodiment is similar to or identical to the network router 112. The network router 122 is coupled to a router 124 in a customer network 126. The router 124 also is similar to or identical to the network router 112. The customer network 126 in an embodiment is typically any well-known local area network (LAN) or wide area network (WAN), including topology, protocol, and architecture, which is well known.

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The network router 122 also is coupled to an alternate channel, such as a backup channel 128. In one embodiment, the backup channel 128 is a T-1 line, which is a well-known dedicated phone connection supporting data rates of 1.544Megabits per second (Mbps).

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An agent 152 and an agent 154 monitor the performance of the optical link through the atmosphere, and may access equipment's state variables (e.g., antenna, transceiver, router, computer, or remote device). To determine whether to route traffic through the backup channel 128, the agents 152 and 154 may employ a computational

10   module, a neural network, or any suitable decision-making technique.

According to an embodiment of the present invention, the agents 152 and 154 are a collection of software modules associated with the transceivers. In one embodiment, the agents 152 and 154 are running on a device embedded in the transceivers. The agents 152

15   and 154 monitor optical information, such as optical detector values and light beam attenuator values for each transceiver. In one embodiment, the agents 152 and 154 determine the quality of the analog signal by monitoring the photon count using an APD and the light beam attenuation using a filter wheel, for example. There may be other ways to determine the quality of the analog signal besides monitoring the photon count using

20   an APD and the light beam attenuation using a filter wheel. For example, when the data is transmitted and received via a radio frequency (RF) carrier a squelch reading on a radio may be used.

The agents 152 and 154 also monitor router information, such as number of

25   packets, number of packet errors, and so forth, accessed from the distribution switches 110 and 120, respectively. The agents 152 and 154 may access optical and router information using a variety of techniques. For example, the agents 152 and 154 may access the distribution switches using a well-known Simple Network Management

Protocol (SNMP) interface. The agents 152 and 154 may access routers using a well-known command line interface (CLI) or well-known remote monitoring (RMON) network management protocol.

5   The agents 152 and 154 are invoked when the quality of the optical signal or the router information is marginal. In the embodiment shown in Figure 1, when the agents 152 and 154 are invoked data, such as customer traffic, is rerouted from the free space transmission medium to the backup channel 128. When the quality of the optical signal or the router information returns to normal, data, such as customer traffic, is routed back to

10   the free space transmission medium from the backup channel 128

A digital signal processor (DSP) 170 and a DSP 172 each control tracking of the light beam for the transceivers 102 and 104, respectively. In one embodiment, the DSP 170 and a DSP 172 positions the transceivers 102 and 104 to ensure the light beam is

15   properly focused.

Figure 2 shows the system 100 in more detail, showing state diagrams of the agents 152 and 154. The agent 152 includes a link quality link module LQMLink 202, a link quality performance module LQMPerf 204, a link quality server module LQMServ

20   206, and a link quality configuration module LQMConfig 208. For every link quality server module there is a link quality performance module.

The LQMLink 202 accesses the distribution switch 110 to monitor router information (e.g., number of packets, number of packet errors, and so forth). The

25   LQMLink 202 also accesses log files, such as   log files 210, which store optical information, to keep track of photon counts and filter wheel settings, for example.

The LQMLink 202 launches LQMPerf 204 and LQMServ 206. The link quality performance module LQMPerf 204 and the link quality server module LQMServ 206 are generated by "Netperf", which is a well-known network performance tester. Other network performance testers may be used to generate the link quality performance module LQMPerf 204 and the link quality server module LQMServ 206.

The LQMConfig 208 accesses a configuration file Config File 211. The Config File 211 configures a link to run an agent in the future. As depicted in Figure 2, there may be a software application interface between the agent 152 and the Config File 211.

The agent 154 includes a link quality link module LQMLink 212, a link quality performance module LQMPerf 214, a link quality server module LQMServ 216, a link quality configuration module LQMConfig 218, a link quality proxy module LQMTouch 220, and a link quality control module LQMCntrl 222.

The LQMLink 212 performs substantially the same or identical function in the transceiver 104 as the LQMLink 202 does in the transceiver 102. In one embodiment, the LQMLink 212 accesses the distribution switch 120 and log files 230. The log files 230 performs substantially the same as or identical function in the log files 210. As depicted in Figure 2, there may be a software interface, such as a Common Application Software Interface, between the agent 154 and the Config File 232.

The LQMPerf 214 performs substantially the same as or identical function in the transceiver 104 as the LQMPerf 204 does in the transceiver 102 and the LQMServ 216 performs substantially the same as or identical function in the transceiver 104 as the LQMServ 206 does in the transceiver 102. The LQMPerf 204 communicates with the LQMPerf 214 to exchange test traffic. The LQMServ 206 communicates with the LQMServ 216 to exchange test traffic. The link quality performance module LQMPerf

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214 and the link quality server module LQMServ 216 are generated by "Netperf", which is a well-known network performance tester. Other network performance testers may be used to generate the link quality performance module LQMPerf 214 and the link quality server module LQMServ 216.

5   The LQMConfig 218 performs substantially the same as or identical function in the transceiver 104 as the LQMConfig 208 does in the transceiver 102. In one embodiment, the LQMConfig 218 accesses a configuration file Config File 232, to test the configuration of the analog (e.g., radio wave, microwave, laser, light, or the like within the electromagnetic spectrum) link and to configure one or more links to run an
10   agent in the future.

        The LQMTouch 220 is a proxy for the LQMLink 202 in the transceiver 104. In one embodiment, the LQMTouch 220 opens a socket in the transceiver 104 and listens to the optical and router information on behalf of the LQMLink 202. The LQMLink 202
15   connects to the LQMTouch 220.

        The LQMLink 202 or the LQMTouch 220 writes a file(s) to indicate the preferred status of the transceiver. For example, the LQMLink 202 may write an "up local" file to indicate that the transceiver 102 should be up and operating, a "down local" file to
20   indicate that the transceiver 102 should be down for customer traffic and operating only for test traffic, an "up remote" file to indicate that the transceiver 104 should be up and operating, or a "down remote" file to indicate that the transceiver 104 should be down for customer traffic and operating only for test traffic. Likewise, the LQMTouch 222 may write an "up local" file to indicate that the transceiver 104 should be up and operating, a
25   "down local" file to indicate that the transceiver 104 should be down for customer traffic and operating only for test traffic, an "up remote" file to indicate that the transceiver 102 should be up and operating, or a "down remote" file to indicate that the transceiver 102 should be down for customer traffic and operating only for test traffic.

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The LQMCntrl 222 monitors and acts on the existence of the files.

Figure 3 is a flowchart 300 depicting an approach to link quality monitoring. In
5   step 302, the LQMLink 202, the LQMLink 212, the LQMCntrl 222, and the LQMTouch
220 are initiated. In one embodiment, Sysmon, which is a well-known network
monitoring tool designed to provide high performance and accurate network monitoring,
initiates the LQMLink 202, the LQMLink 212, the LQMCntrl 222, and the LQMTouch
220.

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In step 304, customer traffic is transmitted from transceiver to transceiver via the
primary channel (free space). The LQMLink 202 and the LQMLink 212, analyze and
integrate the (digital) router information with the (analog) optical information to decide
whether to route customer traffic through the backup channel 128. If the photon count
15   falls below a threshold value, the LQMLink 202 and the LQMLink 212 interpret this as
marginal optical link performance. If the photon count is above a threshold value, the
LQMLink 202 and the LQMLink 212 allows the customer traffic to flow through the
primary channel (via the optical link).

20   In step 306, the LQMLink 202 or the LQMLink 212 detect that the photon count is
below a threshold value. The LQMLink 202 or the LQMLink 212 also may detect that
the number of packet errors exceeds a threshold value. The LQMLink 202 or the
LQMLink 212 also may detect a sudden spike in the number of packet errors or a
sustained increase in the ratio of packet errors to the number of packets transmitted when
25   computed over a parameterized number of samples. The LQMLink 202 or the LQMLink
212 write a "down local" file or a "down remote" file for either transceiver 102 or 104,
respectively. Of course, the link agents 152 and 154 may use other techniques other than
packet error values and the ratio of packet errors to the number of packets transmitted to

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monitor the performance of the optical link through the atmosphere to determine whether to route customer traffic through the backup channel 128.

In step 308, the LQMCntrl 222 detects a "down local" file or a "down remote" file for either transceiver 102 or 104, the LQMCntrl 222 telnets to the network router 122 via the CLI interface to disable the port between the network router 122 and the distribution switch 120. The network router 122 detects that the port between the network router 122 and the distribution switch 120 is disabled and performs a well-known routing technique, such as OSPF, and finds another route for customer traffic, such as through the backup channel 128 to the network backbone 114.

When the port between the network router 122 and the distribution switch 120 has been disabled and customer traffic has been rerouted, in step 310, the LQMLink 202 and/or the LQMLink 212 launch the LQMServ 206 or the LQMServ 216, respectively, and begin sending test traffic via the LQMPerf 204 and the LQMPerf 214, respectively, to test the optical link. The LQMPerf 204 communicates with the LQMServ 206 and the LQMPerf 214 communicates with the LQMServ 216 to send and receive the test traffic across the optical link. The LQMLink 202 or the LQMLink 212 continue to monitor the distribution switches 110 and 120, which will provide the number of packets and the number of packet errors for the test traffic.

This process is iterative and continues until the photon count is above a threshold value and the ratio of packet errors to the number of packets transmitted is below a threshold value. In one embodiment, when the photon count is above a threshold value and the ratio of packet errors to the number of packets transmitted is below a threshold value the agents 152 and 154 continue to hold the port between the network router 122 and the distribution switch 120 disabled for a configurable period of time, to prevent flapping, for example. If the photon count falls below the threshold value or the ratio of

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packet errors to the number of packets transmitted is above the threshold value, the count down of the configurable period of time is reset.

In step 312, when the photon count returns to being above a threshold value and the ratio of packet errors to the number of packets transmitted returns to being below a threshold value for the configurable period of time, this is detected, the LQMLink 202 writes an "up local" file to indicate that the transceiver 102 can come up and receive customer traffic and an "up remote" file to indicate that the transceiver 104 can come up and receive customer traffic. The LQMTouch 222 writes an "up local" file to indicate that the transceiver 104 can come up and receive customer traffic and an "up remote" file to indicate that the transceiver 102 can come up and receive customer traffic. The LQMCntrl 222 detects the "up local" file and the "up remote" file for both transceivers 102 or 104 and telnets to the network router 122 via the CLI interface to enable the port between the network router 122 and the distribution switch 120. When the port between the network router 122 and the distribution switch 120 is enabled, customer traffic flows through the port between the network router 122 and the distribution switch 120 and out to free space, which is the primary channel.

If the LQMCntrl 222 detects a "down local" file or a "down remote" file for either transceiver 102 or 104 after the port between the network router 122 and the distribution switch 120 has been recently disabled, the LQMCntrl 222 telnets the network router 122 via the CLI interface to disable the port between the network router 122 and the distribution switch 120 and the configurable period of time may be reconfigured to a longer period of time. This can be used to prevent flapping as well.

Although embodiments of the present invention are described with respect to an optical free-space communication system, the present invention is not so limited. For example, the present invention may be implemented in any system that transmits and

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receives using an analog transmission medium or that operates in an analog encoding environment.